

## Article

# The Impact of Green Open Space on Community Attachment—A Case Study of Three Communities in Beijing

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**Abstract:** With the development of urbanization in China, the quality of urban life and community attachment have attracted increasing attention of the governments and society. Existing research on community attachment has mainly examined how individual characteristics affect community attachment, such as their length of residence and socioeconomic status. However, some scholars have become interested in exploring the effects of green open space on community attachment. This research examined whether the distribution of green open space in communities had significant effects on community attachment, and both the impact and path were also investigated. Through a questionnaire survey, relevant data in three communities of Beijing were collected. The impact of green open space layout on community attachment was evaluated by using hierarchical regression, and the impact path was examined by using a structural equation model. The results showed that green open space in a community had significant effects on the community attachment, with centralized green open space layout having a greater effect than that of dispersed green open space. Moreover, the more complex the shape of green open space is, the greater the impact is. The degree of satisfaction with the green open space had direct effects on the community attachment. The accessibility and perceived area of green open space could indirectly have an impact on the community attachment by affecting the degree of satisfaction with the green open space. Nevertheless, residents' perceived importance of green open space could affect the community attachment directly and indirectly, as it affects the degree of satisfaction.

**Keywords:** community attachment; community green open space; shape index; structural equation model

## 1. Introduction

With the development of urbanization in China, people's basic needs are gradually being satisfied, and their health and emotional needs have gained increasing attention [1]. The promotion of the community attachment has become the goals of planners and designers [2]. Green open space in communities is an important element in community planning and design. Thus, research on the effects of green open space in a community on the community attachment has theoretical and practical significance to community planning, design, and evaluation.

A community is one of the most important living place, which is important for developing interpersonal relationships. A community is also the place where people gain emotional support and form identities in their social lives [3]. The community attachment is a type of positive emotional established between the individuals and their place of residence [4]. The degree of the community attachment is an important indicator of community prosperity and social development [5], and is

affected by the social environment of the community, communications, and level of participation and satisfaction [4]. Community attachment is defined as the extent and pattern of social participation and integration into the community, and sentiment or affect toward the community [6]. It has a profound effect on individuals' motivation and behavior [7], which can affect one's health status [8]. When people experience community attachment, they feel being interdependent with other residents in the community, as well as with the community [9], and this community attachment reduces personal stresses and contributes to the health and happiness of individuals [10].

Contemporary Chinese society is gradually shifting to an individualized society [11]. With the constantly advancing reform and opening up in China, the urbanization rate in China has gradually increased. As a consequence, the traditional housing form consisting of the "courtyard system" has gradually collapsed, and commercial residential buildings have become the mainstream housing form, resulting in increased mobility of community residents. This new housing form does not promote the opportunities for the shared values and emotional connections between residents that were characteristic of the original "courtyard" system and neighborhoods therein [12]. In addition, many public open space designs are not user-friendly, nor do these new housing forms support social interactions among residents [13]. Thus, the neighborhood declines and the community consciousness of residents becomes weak [14]. Since the residents are not familiar with each other, they rarely visit each other, which results in the lack of community attachment [15] and an increase in health risks [16]. In addition, it is also associated with a variety of negative emotions, such as anxiety, depression, anger, and sorrow [17].

Green open space is essential to cities, and are also an important influencing factor of urban livability [18], contributing to the quality of life [19] and benefiting resident health [20] in numerous ways. A well-designed green open space can encourage interaction [21], which has positive effects on emotional health and health perceptions [22]. Good green open space also can relieve both mental and physical stresses [23]. Dinnie et al. [24] found that green open space also could promote social participation by increasing the frequency and time of outdoor activities. Researchers have found that green open space also has obvious effects on the community attachment. Bow et al. [25] held that community attachment related to the bonds people developed with the natural environment. Based on research about green open space in deprived urban neighborhoods, Ward et al. [26] also pointed out that green open space increase the community attachment and reduce social isolation, thereby promoting the health and well-being of residents.

At present, the research on factors that influence the community attachment mainly concentrates on characteristics of individuals, such as age [27], residential satisfaction [28], and socioeconomic status [29]. Though the above factors have been discussed in research on the interaction between green open space and community attachment, the question of whether green open space layout can affect community attachment remains unanswered in the Chinese context. What kind of green open space layout is more conducive to, or can strengthen the formation of, community attachment? How does green open space affect community attachment? Answering these questions is the overall objective of this research. Accordingly, examinations were carried out from three perspectives.

## 2. Materials and Methods

The hierarchical stepwise regression method was used to analyze the effects of green open space on the community attachment. The effects of different shape characteristics of green open space on the community attachment were compared. Moreover, the correlation between green open space and the community attachment was evaluated using a structural equation model.

### 2.1. Materials

Three typical communities (Baiwanzhuang, Fangguyuan, and Longzeyuan) in Beijing were selected as research areas (Figure 1). The communities are models of community design from different periods in Beijing, and are conducive to research on green open space. The Baiwanzhuang community

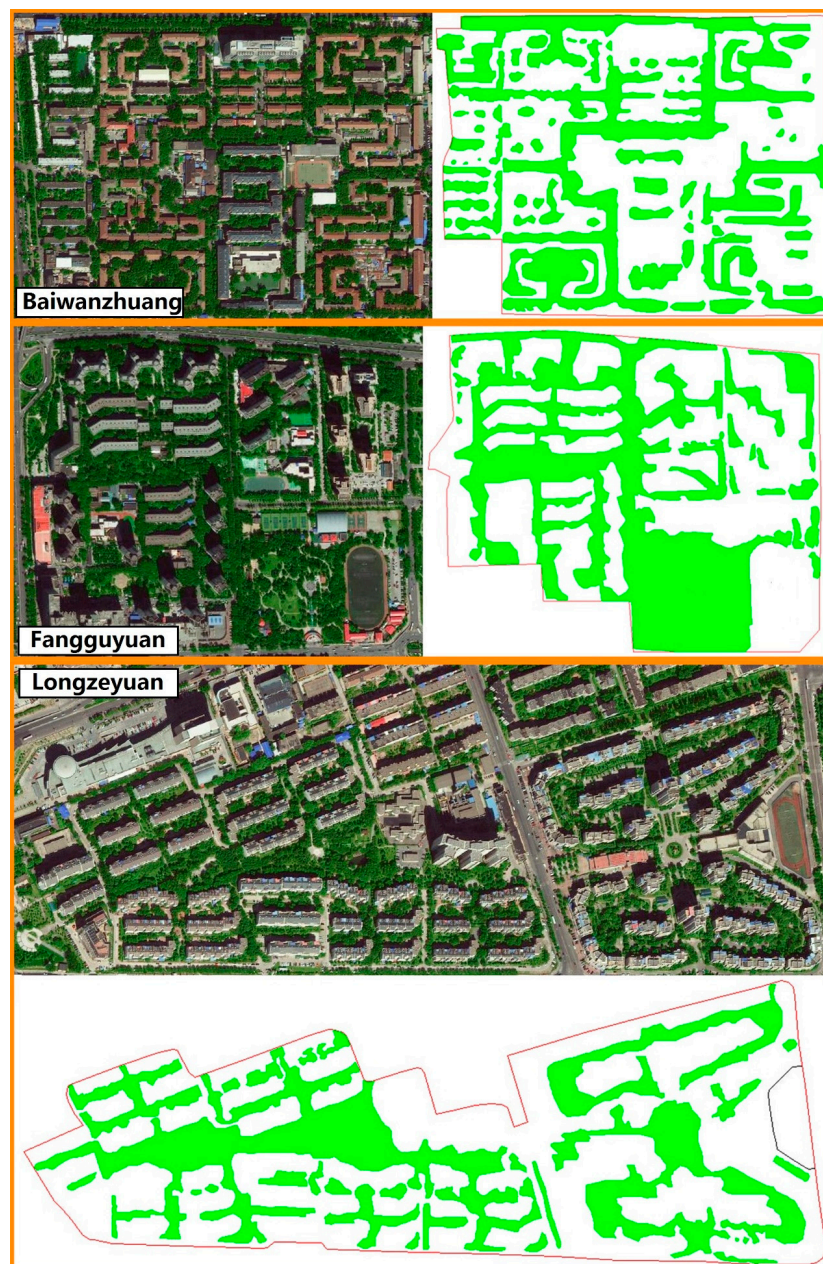
is located within the West Second Ring Road of Beijing and was established in 1951. Baiwanzhuang is the high-class residential quarter planned and designed after the founding of People's Republic of China. The area of its green open space is about 0.12 km<sup>2</sup>. The Fangguyuan community was built at the end of the 1980s and is located in the south of the South Second Ring Road of Beijing. Fangguyuan is a residential quarter in the first large-scale residential district built under city planning in Beijing. The area of its green open space is about 0.14 km<sup>2</sup>. The Longzeyuan community was built in 2004 and is located in the north of the North Fifth Ring Road of Beijing. Longzeyuan is a Sino-American demonstration quarter, planned and designed by an American, and is the first national comfortable housing model project. The area of its green open space is about 0.11 km<sup>2</sup>. A relatively long residence time in a community is beneficial to forming a community attachment [30], enabling us to carry out such research.



**Figure 1.** Locations of Baiwanzhuang, Fangguyuan, and Longzeyuan in Beijing.

To examine how green open space layout affects the community attachment, Google Earth® 5.1 (google: Mountain View, CA, USA, 2009) imaging was used to extract and analyze the green open space in the three communities. As shown in Figure 2, the green open space is distributed around the courtyard buildings relatively evenly in the Baiwanzhuang community, which is in a dispersed layout pattern. In the Fangguyuan community, the green open space is distributed linearly along grid lines in the middle of space separating rows of houses, and there are also wide open spaces, such as the playground and green parks, in the middle of the community. Thus, green open space in Fangguyuan is in a centralized layout pattern. In the Longzeyuan community, green open space is mainly located in the center of the apartment buildings, and shows a zonal distribution as well as a centralized layout pattern [31].





**Figure 2.** Green open space layouts in Baiwanzhuang, Fangguyuan, and Longzeyuan.

## 2.2. Methods

### 2.2.1. Questionnaire Survey

The structured questionnaire was developed in two main sections. One section collects information on the demographic characteristics of the respondents, including gender, age, marital status, occupation, length of residence, expected residence time, Beijing hukou status (i.e., local or migrant), income level, educational level, housing form, whether having a minor child, and other characteristics. The other section was designed to investigate the perception of people to all aspects of green open space. Responses were categorized by using Likert scales [32] from the community attachment and the degree of satisfaction, as well as the perceived area of green open space, accessibility and perceived importance of green open space. Four closed questions (i.e., I do not want to live in other communities (agree or disagree); I have a strong community attachment

(agree or disagree); the community is special to me (agree or disagree); I will be very sad when I leave (agree or disagree)) were used to measure community attachment. Eleven closed questions were used to indicate the degree of satisfaction, perceived area of green open space, accessibility, and perceived importance of green open space. With a stratified random sampling method, we carried out a face-to-face questionnaire survey to residents in the three communities from May to June 2014, and the approval was received from neighborhood committee before undertaking the research.

### 2.2.2. Hierarchical Regression Analysis

Hierarchical regression analysis is based on the regression analysis method, but analyzes the variables in each level separately to determine the difference that each variable causes to the strength of the regression. The basic procedure involves adding a variable of interest to the model at the last step to investigate its contribution to the regression equation when the contributions of the other variables are excluded. In this research, the demographic characteristics of the respondents were regarded as the control variables, and were entered in the Step 1. The respondents' expressed preferences about green open space (including the degree of satisfaction, accessibility, importance and expectations) were considered as the independent variables. The respondents' expressed community attachment was the dependent variable and was entered in the Step 2.

### 2.2.3. Structural Equation Model

A structural equation model can address the problems arising from many dependent variables, and can solve the problem of the multicollinearity of independent variables [33,34]. The overall model consists of a measurement model and structural model. The measurement model aims at establishing the relationship between the measured variable and latent variable. The structural model intends to test the causal path relationship between the variables. The structural pattern of validity in the measurement model is mainly tested by confirmatory factor analysis (CFA), which analyzes the path of latent variables to test the suitability of the overall structural model.

A structural equation model can be expressed as Equations (1)–(3).

The measurement equations are:

$$x = \Lambda_x \xi + \delta \quad (1)$$

$$y = \Lambda_y \eta + \varepsilon \quad (2)$$

The structural equation is:

$$\eta = \beta \eta + \Gamma \xi + \zeta \quad (3)$$

Part of the measurement equation (Equation (1)) describes the relationship between the exogenous latent variable  $\xi$  and the indicator variable  $x$ , and the other part of the measurement equation (Equation (2)) describes the relationship between the endogenous latent variable  $\eta$  and the indicator variable  $y$ , while the structural equation (Equation (3)) describes the structural relationship between the latent variables.

Firstly, we measured the reliability and effectiveness of research tools by exploratory factor analysis, then combining the results described previously on the exploratory factors with information from the existing literature, a structural equation model was developed including five structural variables and 15 measurement indexes (as shown in Table 1) about the relationship between green open space and the community attachment.

The structural equation model was proposed to test the following assumptions:

**Assumption 1.** *Accessibility to a green open space has a direct positive impact on the residents' degree of satisfaction regarding the space.*

**Assumption 2.** *Accessibility to a green open space has a direct positive impact on the community attachment.*

**Assumption 3.** The importance of green open space has a direct positive impact on the residents' degree of satisfaction regarding the space.

**Assumption 4.** The importance of green open space has a direct positive impact on the community attachment.

**Assumption 5.** The perceived area of green open space has a direct negative impact on the residents' degree of satisfaction regarding the space.

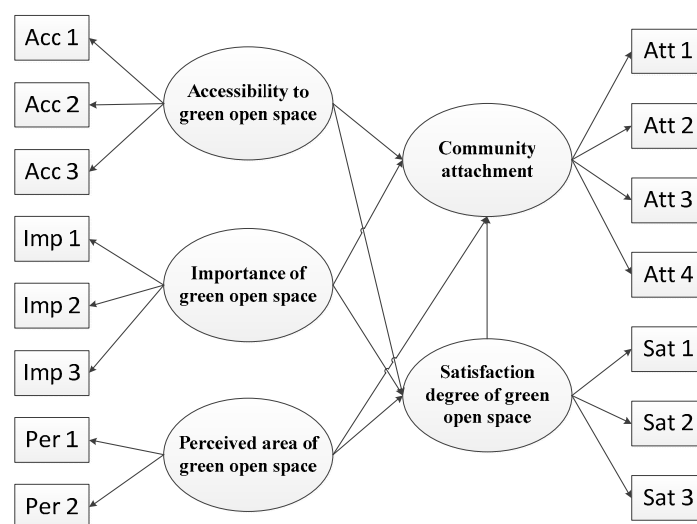
**Assumption 6.** The perceived area of green open space has a direct negative impact on the community attachment.

**Assumption 7.** The degree of satisfaction regarding a green open space has a direct positive impact on the community attachment.

**Table 1.** Structural variables and measurement indices.

Structural Variable	Measurement Index			
Accessibility to green open space	Recreational sites are often visited	Recreational sites are very convenient	Most recreational sites are known	
Importance of green open space	Green open space play an important role in adjusting the climate in the community	Green open space improve life quality	Green open space is very important to life	
Perceived area of green open space	Expect more green open space in the community	Community needs more green open space		
Satisfaction degree of green open space	Whole satisfaction value to the park	Whole satisfaction value to the square	Whole satisfaction value to the green open space	
Community attachment	I do not want to live in other communities	I have a strong community attachment	The community is special to me	I will be very sad when I leave

The relationships of these hypotheses to the various measurement indices are shown in Figure 3.



**Figure 3.** Relationship of the hypotheses in the structural equation model. Note: The following abbreviations are used in this manuscript: Acc 1: recreational sites are often visited; Acc 2: recreational sites are very convenient; Acc 3: most recreational sites are known; Imp 1: green open space play an important role in adjusting the climate in the community; Imp 2: green open space improve life quality; Imp 3: green open space is very important to life; Per 1: expect more green open space in the community; Per 2: community needs more green open space; Sat 1: satisfaction value to the park; Sat 2: satisfaction value to the square; Sat 3: satisfaction value to the green open space; Att 1: I do not want to live in other communities; Att 2: I have a strong community attachment; Att 3: The community is special to me; Att 4: I will be very sad when I leave.

We established the structural equation model by using the software LISREL 8.7 (Scientific Software International, Inc., Lincolnwood, IL, USA, 2004). According to the principles of “T-minimum-cut path” and “M-maximum-add path”, the model was corrected stepwise by combining the relevant theories.

#### 2.2.4. Land Shape Index

When applied to green open space, the landscape shape index (LSI) can quantitatively represent the complexity of green open space shapes, and is calculated using Equation (4):

$$LSI_i = \frac{P_i}{2\sqrt{\pi \times a_i}} \quad (4)$$

where  $LSI_i$  is the shape index,  $P_i$  is the perimeter of the green patch, and  $a$  is the area of the green patch [35]. Under the equal-area condition, as the circumference of a circle is the shortest path around a given area, when  $LSI_i = 1$ , the green patch is round. The larger the value of  $LSI_i$ , the more complex the geometrical shape of the green patch. Using Equation (4), the LSI of each green open space in all communities was calculated, and the average value was taken as the shape index of the green open space in the community.

### 3. Results

In the three communities, 440 questionnaires were sent to residents and 423 questionnaires were collected, including 410 valid questionnaires, resulting in an effective return rate of 96.93%. Among the valid questionnaires returned, 111, 155, and 144 came from Baiwanzhuang, Fangguyuan, and Longzeyuan communities, respectively. The preliminary data contained in the valid questionnaires were analyzed using the software SPSS21.0. The structural features of survey samples were basically in line with the features of the residents in the communities. The reliability of the 410 valid questionnaires was also analyzed using SPSS21.0 (IBM: Armonk, NY, USA, 2013). The reliability coefficient of Cronbach’s  $\alpha$  was 0.819, which was larger than the recommended value of 0.7 and confirmed the good internal consistency of indicators in the questionnaire. All observable variables were deemed to be credible and possess good reliability [36].

The descriptive statistics of samples collected from the three communities are shown in Table 2. The residence time of respondents in the communities was long, and about half of the respondents had lived in the community for more than 10 years. A comparison of the demographic characteristics of respondents in the three communities shows that the age group of respondents in the Baiwanzhuang community is older than for the other two communities, the number of local residents is greater, and the average residence time is longer. In the Longzeyuan community, the respondents are younger than in the other communities, the proportion of migrant residents is larger, and the average residence time is shorter. The main cause for these differences is that the Baiwanzhuang community was established in 1950s, and is the original community for staff housing of China’s state organizations. In contrast, the completion year of Longzeyuan is the most recent of the three communities, and there is a large number of young migrants living in Longzeyuan. The structural features of survey samples are basically in line with the features of residents in communities established in different periods, and are suitable for further analysis.

**Table 2.** Statistics of demographic characteristics of respondents.

Characteristics	Classification	Total (%)	Baiwanzhuang (%)	Fangguyuan (%)	Longzeyuan (%)
Gender	Male	42.4	37.8	47.7	40.3
	Female	57.6	62.2	52.3	59.7
Age	Aged Under 18	2	1.8	1.9	2.1
	Aged 18–65	79.5	58.6	88.4	86.1
	Aged 65 and over	18.5	39.6	9.7	11.8



Table 2. Cont.

Characteristics	Classification	Total (%)	Baiwanzhuang (%)	Fangguyuan (%)	Longzeyuan (%)
Marital status	Married	88.5	93.7	84.5	88.9
	Unmarried	10	2.7	14.8	10.4
	Divorced, widowed or others	1.5	3.6	0.6	0.7
Length of residence time	Less than 1 year	11	4.5	10.3	16.7
	1–5 years	24.1	12.6	28.4	28.5
	6–10 years	17.3	5.4	16.8	27.1
	More than 10 years	47.6	77.5	44.5	27.8
Beijing hukou status	Local residents	63.9	86.5	69.0	41.0
	Migrants	36.1	13.5	31.0	59.0
Monthly income	Less than 3000 yuan	25.6	34.2	26.5	18.1
	3000–5000 yuan	25.9	32.4	31.0	15.3
	5000–7000 yuan	25.6	25.2	27.7	23.6
	More than 7000 yuan	22.9	8.1	14.8	43.1
Education level	Junior middle school and below	18	26.1	21.9	7.6
	Senior middle school or junior college	35.6	45.9	34.2	29.2
	University	34.9	24.3	33.5	44.4
	Master and above	11.5	3.6	10.3	18.8
Employment	Housewife	7.8	10.8	6.5	6.9
	Student	1.7	0.9	1.9	2.1
	Retiree	36.1	62.2	27.1	25.7
	Employed	23.4	11.7	27.7	27.8
	Self-employed	31	14.4	36.8	37.5

### 3.1. Effects of Green Open Space on Community Attachment

The hierarchical regression analysis of the data collected from Baiwanzhuang, Fangguyuan, and Longzeyuan was conducted using SPSS21.0. As shown in Table 3, according to the *t*-test, the residence time and expected residence time of respondents are significantly associated with their community attachment, while the occupation of the respondent also has a significant effect on their community attachment. The results show that  $R^2_{adj}$  in the first step of the regression analysis was 0.267, which means that the demographic characteristics explained 26.7% of the community attachment. In the second step,  $R^2_{adj}$  was 0.428, which indicates that the demographic characteristics and green open space indicator together explain 42.8% of the community attachment. When the effects of the demographic characteristics were excluded, the indicator of green open space had obvious effects on the community attachment, explaining 16.1% of their community attachment (Table 4). Similarly, comparative analysis of the degree of impact of the green open space indicator on the community attachment in the three communities showed that the indicator of green open space explained 16.5%, 24.5%, and 31.9% of the community attachment in Baiwangzhuang, Fangguyuan, and Longzeyuan communities, respectively. Therefore, there are significant differences between the extent to which the effect of green open space indicators explain the community attachment in the three communities, with the impact being greatest in the Longzeyuan community and least in the Baiwanzhuang community.



**Table 3.** Results of multi-layer stepwise regression analysis.

Items	Total		Baiwanzhuang		Fangguyuan		Longzeyuan	
	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2
<b>Control variable</b>								
Residence time	6.599 ***	9.445 ***	3.817 ***	4.173 ***	1.758	2.989	0.475	1.282
Expected residence time	6.366 ***	6.589 ***	4.130 ***	4.671 ***	4.244 ***	3.716 ***	4.130 ***	4.680 ***
Beijing hukou status	−0.262	0.121	−2.162 *	−1.702	0.567	−1.118	−0.969	−1.072
Income level	−1.481	−2.355	−3.418 ***	−3.794 ***	−1.293	−0.643	0.151	0.529
Occupation	−2.465 *	−3.345 ***	0.337	−0.416	−0.662	−0.872	−1.976	−1.276
Educational level	−1.404	−2.863	−1.358	−1.812	−2.445 *	−3.885 ***	0.725	1.628
<b>Satisfaction with green open space</b>								
Overall satisfaction value of community park	−	−0.275	−	2.186 *	−	0.245	−	1.255
Overall satisfaction value of community square	−	4.532 ***	−	1.186	−	4.485 ***	−	5.564 ***
Overall satisfaction value of green open space	−	3.543 ***	−	2.477 *	−	0.851	−	1.572
<b>Accessibility to green open space</b>								
Often going to the recreational sites in green open space	−	1.910	−	1.356	−	2.334 *	−	3.305 ***
Knowing most recreational sites in green open space	−	1.725	−	0.692	−	0.651	−	0.454
<b>Importance of green open space</b>								
Green open space improve life quality	−	4.035 ***	−	−0.025	−	5.163 ***	−	1.894
Green open space is very important for life	−	−0.208	−	2.034 *	−	−0.769	−	0.201
<b>Perceived area of green open space</b>								
Expecting more green open space in their community	−	2.451 *	−	2.772 **	−	0.483	−	−0.631
(Constant)	−5.005 ***	−9.940 ***	−1.140	−4.746 ***	−1.572	−6.827 ***	−3.872 ***	−8.857 ***
R <sup>2</sup>	0.272	0.438	0.407	0.582	0.152	0.406	0.107	0.432
R <sup>2</sup> <sub>adj</sub>	0.267	0.428	0.384	0.549	0.141	0.386	0.101	0.420
F-value	50.615 ***	44.729 ***	18.171 ***	17.746 ***	13.608 ***	20.330 ***	17.053 ***	35.468 ***

Note: \* significant at  $p < 0.05$ ; \*\* significant at  $p < 0.01$ ; and \*\*\* significant at  $p < 0.001$ .

**Table 4.** Explanation degree of green open space.

	<b>Totality</b>	<b>Baiwanzhuang</b>	<b>Fangguyuan</b>	<b>Longzeyuan</b>
$R^2_{adj}$ (Step 1)	0.267	0.384	0.141	0.101
$R^2_{adj}$ (Step 2)	0.428	0.549	0.386	0.420
Explanation degree of green open space	0.161	0.165	0.245	0.319

Note: Explanation degree of green open space =  $R^2_{adj}$  (Step 2) –  $R^2_{adj}$  (Step 1).

### 3.2. Effects of Green Open Space Layout on Community Attachment

The above analysis shows that there are significant differences between the degrees to which the effects of green open space explain the community attachment. To examine whether green open space layouts have impacts on community attachment, we compared the layouts of three communities. The shape index of green open space was compared with the degrees to which indicators of green open space explained the community attachment (Table 5).

**Table 5.** Comparison of green open space in three communities.

	<b>Baiwanzhuang</b>	<b>Fangguyuan</b>	<b>Longzeyuan</b>
Landscape shape index (LSI)	1.49	1.63	1.97
Layout pattern of green open space	Dispersed-type	Centralized-type	Centralized-type
The degree to which green open space explain the community attachment (%)	16.5%	24.5%	31.9%

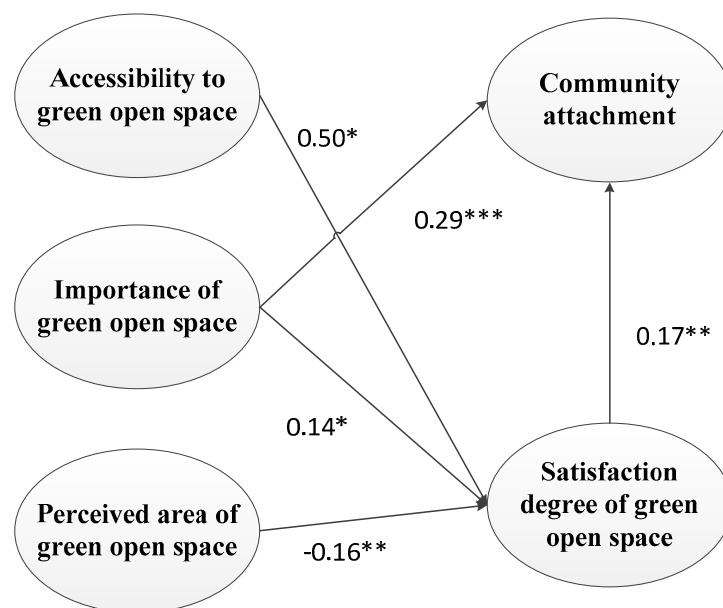
The results shown in Table 5 reveal that the degree to which green open space explains the community attachment is greater for green open space distributed in the form of a centralized layout than for green open space distributed in a dispersed layout; consequently, the impact on the community attachment is greater for centralized green open space than dispersed green open space. In the Baiwanzhuang community, where the green open space is of a dispersed layout, the contribution of green open space to the community attachment is the smallest of the three communities. Additionally, LSI values correlate positively with the degree in which green open space explains the community attachment in the three communities. The larger the LSI is, the more complex the green open space. The greater the degree in which green open space explains the community attachment is, the greater the impact on the community attachment.

### 3.3. Impact Path of Green Open Space on Community Attachment

In order to study the mechanism of the green open space affecting the community attachment in this study, we established the structural model shown in Figure 4. The ratio of the chi-square value to the degree of freedom of the final model is 2.06, and the fit index (root mean square error of approximation, RMSEA) is 0.049 (smaller than 0.08, which is desirable) and the comparative fit index (CFI) is 0.97 (larger than 0.9, which is desirable), indicating that the fitting model is a “good” model [37].

Results from the structural equation modeling show that residents’ degree of satisfaction about the green open space has a significant positive correlation with their community attachment (the path coefficient is 0.17). The accessibility to green open space has no direct correlation with the community attachment; however, the accessibility can have indirect positive effects on the community attachment by influencing the degree of satisfaction about the green open space in the community. The path coefficient is the product of two coefficients (i.e.,  $0.50 \times 0.17 = 0.09$ ). The perception of the residents to the importance of the green open space has both direct and indirect effects on their community attachment. The direct correlation coefficient between the importance of green open space and the community attachment is 0.29, while the indirect correlation coefficient generated by influencing the satisfaction degree is 0.02. Thus, the correlation coefficient between the importance of green open

space and a community attachment is 0.31. The expectation of residents about the green open space is indirectly positively correlated with their community attachment by the influence of their degree of satisfaction, and the correlation coefficient is  $-0.03$ .



**Figure 4.** Impact path of green open space on the community attachment. Note: \*\*\* significant at  $p < 0.001$ ; \*\* significant at  $p < 0.01$ ; and \* significant at  $p < 0.05$ .

#### 4. Discussion

The results of this study showed that green open space had significant impacts on the community attachment, and this finding is consistent with the research findings of Salleh [38]. In contrast to dispersed green open space layouts, centralized green open space provides sites for leisure activities, and increases the opportunities for residents carrying out community activities. As a result, it increases face-to-face contact among neighbors, increasing the social integration and social interactions [39]. Consequently, it helps build trust, mutual understanding, shared values, and supportive behaviors [40]. Therefore, centralized green open space is beneficial to improve the neighborhood and enhance the community attachment [41]. Additionally, green open space with complex shapes may improve the community attachment. Green open space with complex shapes increases the boundary of the space, and increases the possibility for residents to interact with the wide open space. Thus, the perception level of the residents to complex green open space is larger than to the less complex space. The complex green open space also increases people's psychological perception on the green open space and promotes the value of it. Therefore, the satisfaction degree of residents and community attachment is increased in the communities with complex green open space.

The results also showed that the degree of residents' satisfaction to green open space is positively correlated with community attachment. The green open space is an important part of the community, and the residents' satisfaction is their subjective perception of the quality of the community environment [42]. The residents' satisfaction with the green open space reflects their satisfaction with the community to some extent [43], while the residents' satisfaction with the community were greatly correlated with their community attachment [44]. Therefore, there is a positive correlation between the residents' satisfaction to the green open space and their community attachment.

The accessibility to green open space has significant impacts on the degree of satisfaction of residents to the green open space and, thus, affect the community attachment. The higher the accessibility to green open space, the lower the time cost for the resident, and the more frequent the utilization and the higher the degree of satisfaction with the green open space, which increases

community attachment. Coombes [45] also found that the reported frequency of green open space use declined with the increasing distance, and improving access to green open space could promote greater participation in physical activities.

The importance of green open space could not only directly affect the community attachment, but also indirectly influence it by impacting their degree of satisfaction. On the one hand, green open space is an important part of the community. When the residents value highly the importance of the green open space, they have a stronger sense of belonging to the community [46]. Meanwhile, the residents that value highly the importance of green open space also suggest that they use the green open space frequently. Thus, there is a direct positive correlation between residents' evaluation of the importance of green open space and their community attachment. On the other hand, the residents consider that the green open space in the community plays important roles. How residents value the importance of green open space in the community also affects the degree of satisfaction of the residents with the green open space in the community. Hence, the importance evaluation of residents about the green open space may generate an indirect positive correlation with their community attachment through a sense of satisfaction. The higher the importance evaluation of residents on the green open space is, the stronger their community attachment is.

Additionally, we found that the perceived area of green open space has significant impacts on community attachment. According to Kim et al. [47], expectation is the core element of the degree a satisfaction—the greater the expectation, the greater the disappointment. When the expectation of a resident for green open space in the community is higher than the actual situation, the dopamine-producing cell activities in the resident's brain are blocked [48], leading to a feeling of depression and dissatisfaction towards the community. Galster et al. [49] found that the closer the expected housing conditions to the actual housing conditions, the higher the residential satisfaction. Accordingly, the expectation of residents to green open spaces can generate indirect negative effects on their community attachment by influencing their degree of satisfaction. Thus, the greater the expectation of residents to the green open space is, the poorer their community attachment is.

## 5. Conclusions

In the three Beijing communities examined, green open space had significant effects on the community attachment, and the strength of this effect varied with different green open space layouts. Green open space that had complex layouts were conducive to forming a community attachment in the residents and increasing their perception on the value of the green open space. Furthermore, centralized green open space could provide communication space for the residents and enhance the social bonds among the residents, thereby promoting the community attachment. In terms of impact path, residents' degree of satisfaction about the green open space had direct effects on the community attachment. The accessibility to, and perceived area of green open space, have impacts on the satisfaction degree of residents to the green open space and, thus, both affect the community attachment. The importance of green open space could not only affect the community attachment directly, but also indirectly influence it by impacting their degree of satisfaction. The results also showed that community attachment was promoted where green open space with a complex shape was provided. Considering the complexity of shape, it calls for more studies to examine the relation of the shape index and community attachment.

This research was exploratory. Due to data limitations, it requires further study. For example, the number of communities examined and the total sample size of residents surveyed can be increased to verify the conclusions reached in this study. In addition, describing the "quality" of green open space only by the shape index was over-simplified. In the future study, it can include more indicators, such as plant structure and space construction, to better explore the contribution of the green open space layout to community attachment. Furthermore, future research can also explore the effects and action mechanisms of green open space layout on the mental and physical health of residents.



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